

Q&A

WITH TJ BYERS

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments, or suggestions.

You can reach me at: TJBYERS@aol.com

ALL ABOUT SNUBBERS

Q Could you explain the following terms: di/dt and dv/dt ? How should they be taken into consideration when working with both small- and high-power SCRs?

— Z.F.

Q I have seen many circuits in *Nuts & Volts* over the years that use triacs to switch AC loads. Now I want to switch a sump pump on and off using a triac. However, I can't find a simple explanation on when a snubber circuit is required and when it's not. To add to the confusion, I have seen references to new triacs that do not require

snubbers. Know of any guidelines on snubber design and the values of the required components?

— John Cox
Nova Scotia, Canada

A I've put off this discussion for about two years now because of the math, where I have to distill calculus and imaginary numbers into everyday numbers for the hobbyist. The following equations are sometimes approximations, but close enough that they fall within the realm of everyday life. For the first part of the discussion, I will focus on the SCR, simply because the artwork is easier to draw, but what is said applies to both the SCR and triac.

Let's begin with di/dt — the rise in current through the SCR or triac in relationship to time. This is the amount of current (di) that the SCR experiences immediately

WHAT'S UP:

A text-book tour on designing snubbers. I've put this off for a long time because of the math, but the questions kept on a-comin'. So here it is. I also made room for the following:

- ✓ DOS is alive and well.
- ✓ AND logic with diodes.
- ✓ Expanded scale meters.
- ✓ Battery wet/dry quiz.

Switching

FIGURE 1

Parameter	10RIA	Units	Conditions
di/dt Max. rate of rise of turned-on current	$V_{DRM} \leq 600V$ 200 $V_{DRM} \leq 800V$ 180 $V_{DRM} \leq 1000V$ 160 $V_{DRM} \leq 1600V$ 150	A/ μs	$T_J = T_J \text{ max.}, V_{DM} = \text{rated } V_{DRM}$ Gate pulse = 20V, 15 Ω , $t_p = 6\mu s$, $t_r = 0.1\mu s \text{ max.}$ $I_{TM} = (2 \times \text{rated } di/dt) A$
t_{gt} Typical turn-on time	0.9	μs	$T_J = 25^\circ C$, $a_t = \text{rated } V_{DRM}/V_{RRM}$, $T_J = 125^\circ C$
t_{rr} Typical reverse recovery time	4		$T_J = T_J \text{ max.},$ $I_{TM} = I_{T(AV)}, t_p > 200\mu s$, $di/dt = -10A/\mu s$
t_q Typical turn-off time	110		$T_J = T_J \text{ max.}, I_{TM} = I_{T(AV)}, t_p > 200\mu s$, $V_R = 100V$, $di/dt = -10A/\mu s$, $dv/dt = 20V/\mu s$ linear to 67% V_{DRM} , gate bias 0V-100W

(*) $t_q = 10\mu s$ up to 600V, $t_q = 30\mu s$ up to 1600V available on special request.

Blocking

Parameter	10RIA	Units	Conditions
dv/dt Max. critical rate of rise of off-state voltage	100	V/ μs	$T_J = T_J \text{ max. linear to } 100\% \text{ rated } V_{DRM}$
	300 (*)		$T_J = T_J \text{ max. linear to } 67\% \text{ rated } V_{DRM}$

(**) Available with: $dv/dt = 1000V/\mu s$, to complete code add S90 i.e., 10RIA120S90.

after turning on. The inrush current is determined by the load resistance and normally applies to resistive loads, such as lamps. If the di/dt current exceeds the di/dt listed on the datasheet, kiss your melted SCR good-bye.

For example, let's take International Rectifier's 10RIA20, which is rated 10 amps at 200 volts. The 10RIA20 datasheet (Figure 1) lists di/dt as 200A/ μ s. That is, the maximum load at start-up is 200 amps. Theoretically, the 10RIA20 should be able to switch a 1,200-watt halogen lamp at 120 VAC — until you do the math. (If the datasheet doesn't list di/dt , it is approximately equal to the non-repetitive surge current, I_{TSM} .)

Typically, the inrush current of a tungsten lamp is 20 times the operating current. If the current of the lamp is 12 ohms during operation, then its cold resistance is about 0.6 ohms — enough current to exceed the di/dt of the SCR.

The cure is to insert an inductor in series with the load, as shown in Figure 2. The size of the inductor is calculated by $L = V_{PEAK} / di/dt$. Plugging the numbers into the example above, we get $L = 169 / 200 \times 10^6 = 0.8 \mu$ H. Don't want to use an inductor? Then the math tells us that the lamp should be limited to 900 watts. If the load is inductive — like a motor — you can ignore di/dt .

Inside the SCR are three parasitic capacitors — one of which is connected between the anode and the gate (Figure 3). And like all caps, it

conducts current until it's fully charged. When power is first applied — like closing a switch or breaker — current rushes in to charge this cap. If the current through this cap exceeds the trigger current of the SCR's gate, the SCR turns on. The critical rate of applied voltage is defined as dv/dt — the rise in voltage across the SCR in relationship to time. Here's where the snubber comes in.

A snubber can be as simple as a parallel capacitor or as complex as an RC network (Figure 4). In circuit (a), a capacitor — several times the value of the phantom capacitor — bypasses the surge current. Its value is calculated by $C = V_{DRM} / (R_L \times dv/dt)$. For the 10RIA20:

$$V_{DRM} = 200 \text{ volts}$$

$$I_{TSM} = 200 \text{ amps}$$

$$dv/dt = 100 \text{ V}/\mu\text{s}$$

Let's assume R_L equals 24 ohms —

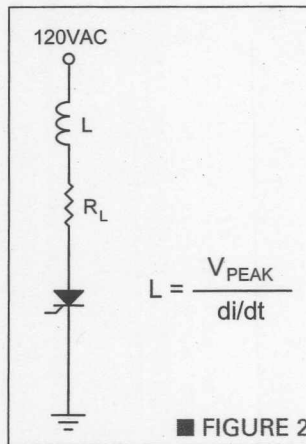
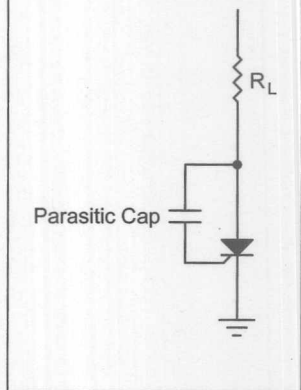


FIGURE 2

FIGURE 3



5 amps at 120 VAC. Plugging the values in, we get $C = 200 / (24 \times 100 \times 10^6) = .083 \mu$ F. I'd use a 0.1 μ F, 200 volt cap.

Once the SCR turns on, though, the charge stored in the capacitor is forced to discharge through the SCR — a discharge current that can exceed di/dt . To prevent this from happening, a small series resistor is inserted (b). The value of this resistor equals $R_s = 10 V_{PEAK} / (I_{TSM} - I_{LOAD (peak)})$. For a 120 VAC circuit, this becomes $R_s = 10 \times 169 / (200 - 7) = 8.8$ ohms. I'd use 10 ohms. The amount of peak current flowing

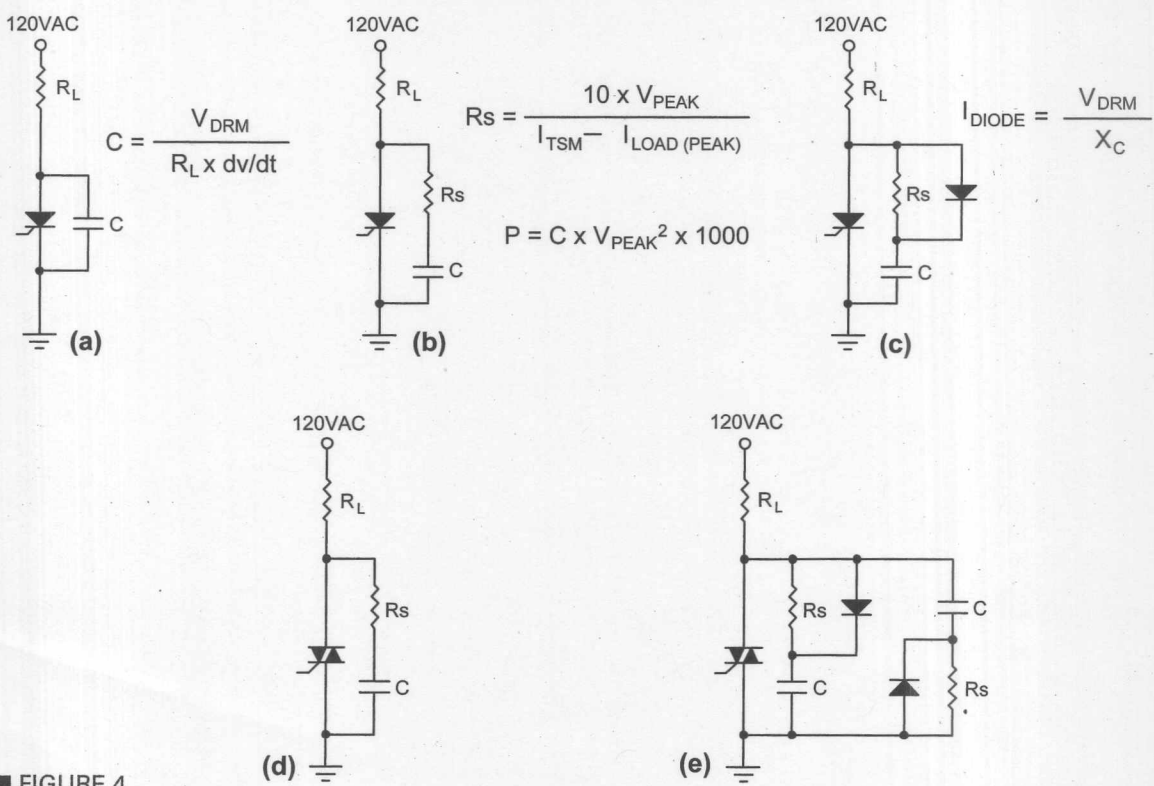


FIGURE 4

Diode AND Gate

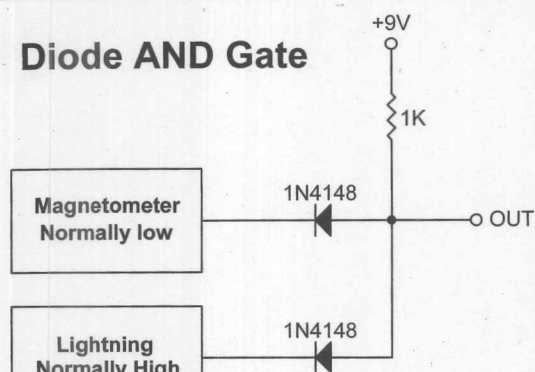


FIGURE 5

through the RC snubber is $I = V_{PEAK} / R = 169 / 10 = 16.9$ amps — well within the di/dt limit of 200 amps. The wattage of R_s is calculated using $P = C \times V_{PEAK}^2 \times 1000 = 0.1 \times 10^{-6} \times 169^2 \times 10^3 = 2.9$ watts.

For this snubber to work, R_s must be smaller than R_L . Otherwise the snubber capacitor will have little effect on suppressing the dv/dt spike. A way around this is to use the circuit in (c), where a diode is added to bypass the charging current around R_s . This way, R_s limits current only when C discharges. As an added benefit, the wattage of R_s is halved to 1.5 watts. The peak diode current is $I_{DIODE} = V_{DRM} / X_c$, where X_c is the capacitive reactance of C at (typically) 1 kHz. Plugging in the values, we get: $I_{DIODE} = 200 / 1592 = 0.13A$. I'd use a 1N4003.

Want to use a triac instead? If $R_s < R_{LOAD}$, then use the snubber in circuit (d). Otherwise, use circuit (e). As to the new non-snubber triacs ... let me see if I can explain. What the semiconductor engineers have done is change the geometry of the triac so that the size of the junction is smaller, which means less parasitic capacitance and less dv/dt impact. In fact, STmicroelectronics claims a 3x improvement with their snubless triacs over

conventional triacs.

Does this mean you can build triac switchers without worry of adding a snubber? Not exactly. Repetitive overvoltage V_{DMR} conditions — like the kind found in switching DC/DC converters — will cause false triggering and possible massive destruction in an improperly compensated design. Higher switching frequencies, too, add to the dv/dt problem. So are

snubbers obsolete? Not today.

DIODE AND LOGIC

I have a magnetometer driveway detector. When it senses a vehicle, I route a nine-volt signal to an interface box that's watched by a recycled PC, which randomly plays WAV files that say "We are being invaded" or something similar. My problem is that weather-lightning drives the driveway detector crazy. I want the PC to check a lightning detector and not play the message if lightning is found. I have an MML101 lightning detector that sounds a buzzer for one second from a nine-volt battery when a strike occurs. How can I put the two together so that when the two events coincide, the PC won't play the message?

— Harvey Lewis
Greenwood, AR

What you need is an AND logic circuit. Not the kind built with 40xx or 75LSxx chips, but with two diodes and one resistor (Figure 5). Your magnetometer is a logic low at rest, and a logic high when it detects a car or lightning strike. The MML101, on the other hand, is logic high until a lightning strike happens. Rather than trying to explain this in words, look at Table 1. The way an AND gate works is that if either of the voltage sources are low, the voltage to the

Lightning	Logic	Magnetometer	Logic	Output
N	H	Y	H	H
Y	L	Y	H	L
N	H	N	L	L

TABLE 1. AND Logic Table.

PC is about 0.7 volts. When both go high — the coincidence of no lightning and the presence of a car — the output goes high and sets off your PC's WAV file.

THE COLOR WHITE

I have two things I wish to power. First, a RadioShack Microanta 63-641 flux gate compass. I removed the plug a long time ago and now want to connect it to another car. The power cable has one black wire and another with a white stripe. I also have a couple of Toshiba T2200Sx laptop computers without power supplies. The laptops require 18 VDC, which should be easy to do. However, I don't know which pins on the connectors are which and where to find a compatible connector.

— Bryan McPhee

About the RadioShack compass. Convention has it that the solid color (be it black, red, or yellow) is hot and the striped white or solid white is negative or neutral. As for the Toshiba notebooks, they can't run from an 18-volt wall-wart. The missing 18-volt power pack is, in actuality, a battery charger. It is very specialized to meet the requirements of the batteries inside the notebook for a quick recharge. Try looking on eBay.com for a suitable replacement. You only need one charger for both notebooks — provided they still have a viable battery pack. Don't ever use a notebook without a battery pack — even if it plugs into the cigarette lighter. Doing so will fry the PC. Cards and emails on this subject, okay!

MAKING THE CONNECTION

Can you suggest two simple circuits for the following purposes?

1. To connect my MP3 player (match box type) with the earphone output jack to my sound system with